National Aeronautics and Space Administration

SEARCH FOR EARTH-LIKE PLANETS STRATEGIC ROADMAP COMMITTEE

March 29–30, 2005

Nassau Inn
Princeton, New Jersey

MEETING REPORT

Ghassem Asrar **Co-Chair**	**Adam Burrows** **Co-Chair**
David Spergel **Co-Chair**	**Eric Smith** **Designated Federal Official**

Search for Earth-like Planets Strategic Roadmap Committee
March 29–30, 2005
Nassau Inn
Princeton, New Jersey

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Tuesday, March 29

Welcome and Introductions

Eric Smith, the Designated Federal Official for the Search for Earth-Like Planets Strategic Roadmap (SRM) Committee, opened the meeting and welcomed the members and guests. He announced that committee members who had missed the ethics briefing for Special Government Employees at the first meeting would be briefed in a special teleconference session at 5:30 p.m. Geoff Marcy and Frank Martin have received waivers from the NASA Administrator to participate in committee deliberations despite potential conflicts of interest under the ethics statutes. Maureen Heath will recuse herself from discussions in which she may have a potential conflict of interest.

Dr. Smith noted that this meeting will have more working discussion and less formal presentation time than the first meeting in February. He reviewed late changes to the meeting agenda and the meeting requirements under the Federal Advisory Committee Act (FACA).

David Spergel, a committee co-chair, welcomed the members. He will chair the meeting of the NASA Space Science Advisory Committee (SScAC), which is starting in Washington, DC, on March 30. The committee discussed the role of the SScAC review of input from the SRM Committees and the integration process for formulating a NASA Integrated Strategic Architecture (ISA) from all of the SRMs and capability roadmaps (CRMs).

Adam Burrows, a committee co-chair, reviewed the work to be done at this meeting to prepare for the April 15 presentation to a National Academies/National Research Council (NRC) review panel. This meeting of the SRM Committee will be used to review and decide on revisions to the content and format of the draft report on the Search for Earth-Like Planets SRM and the April 15 presentation. Dr. Burrows asked the members and guests for suggestions of additional meeting objectives.

Anne Kinney, Director of the Universe Division in the Science Mission Directorate (SMD), asked the committee to consider the addition of a new competed line for directed missions. In particular, she asked how the committee would rate such a program with respect to the current set of proposed missions in the Universe Division. The approximately $250 million of annual funding would come from the Division budget of $1.5 billion as currently programmed. The future missions that would be most affected would be those in the Beyond Einstein and Navigator programs. A competed line is being considered, she said, because the division's budget is currently tied up in strategic missions. The staff has begun thinking about options to balance the large missions with smaller missions that can be achieved in a shorter time. In response to a member's question, Dr. Kinney discussed options for a competed program line directed within Universe Division through use of funds from current competed programs such as Discovery and Explorer. Dr. Smith said that further details on a competed line option would be presented to the committee for discussion later in the meeting.

Outline and Progress Reports on Proposed Strategic Roadmap

The discussion of other objectives for the meeting evolved into discussion of the status of the SRM draft, which was the next agenda topic. Dr. Burrows continued leading the discussion.

John Mather asked how this SRM should address various overlaps with other areas in the Universe Division, such as overlaps with observatories primarily intended for wide-field surveys. In addition to inter-SRM dependencies, some missions may be very strong in both planet-finding and other objectives. Dr. Burrows responded that the committee should review carefully and revise the section on inter-roadmap dependencies in the draft roadmap report. The James Webb Space Telescope (JWST) and other missions cover several areas, which the report should reflect. A legacy roadmap was prepared over the past year by teams organized to reflect the former Astronomy and Physics themes, which are now combined in the Universe Division. The legacy roadmap has detailed discussion of these overlaps and can be used for the SRM as a source for high-level statements on shared objectives.

Neil Tyson, who was unable to attend the first meeting of the committee, asked about the outcome of the "homework assignment" for members to give their vision of planet-finding science in 2035. He was particularly interested in whether members' views reflected primarily past paradigms for observatory spacecraft and other hardware or included novel approaches. Dr. Smith said that some interesting ideas were brought out, which are captured in the minutes of that meeting. The minutes are now available.

Alycia Weinberger said that, although the draft document has a clear vision for planet hunting, it is not clear about missions to investigate planet formation beyond the next 10 to 15 years. She requested that the report state strongly that simply finding planets is not enough to achieve the roadmap's objectives. It is also necessary to understand how the planets got there and how planets evolve.

Dr. Kinney said that concerns had been expressed at the Universe SRM (SRM 8) Committee meeting about planet-finding absorbing all of the NASA budget for astronomy and physics. The Search for Earth-Like Planets SRM Committee agreed with her suggestion that its roadmap report should note the time allotments for non-planet-finding science included in the planning for major observatories. The committee discussed the potential impact of the Space Interferometry Mission (SIM) descope on loss of observing time for science objectives other than planet-finding and whether to emphasize the multiple capabilities of platforms in the strategic roadmap or in the legacy roadmap, which covers all of Universe Division science objectives.

As a general comment on the current draft of the roadmap, Dr. Marcy said that it understates the missions and investigations undertaken by other entities than NASA, including the National Science Foundation (NSF), the Department of Energy (DOE), and the European Space Agency (ESA). The report should describe how results from projects such as the Atacama Large Millimeter Array (ALMA) will contribute to planet-finding. After discussion, the committee generally agreed that the roadmap report should be clear about the contributions from other projects and investigations, including Gaia, Darwin, and Corot. Dr. Burrows said that the existing section on contributions from non-NASA missions will need enhancement.

Dr. Burrows gave an overview of the current draft and of changes he had made recently. He highlighted sections where additional work is needed. Interdependencies among missions will be important. The committee will need to work on decision points (branch points); for example, a branch in pathways if the results from Corot and Kepler show that planets are either much rarer or

much more common than currently thought. Dr. Burrows also suggested that overlaps between the section with mission synopses and other sections be removed. With respect to dependencies among the roadmaps, Appendix 4 should have bullets added to strengthen the connections with other strategic objectives than planet-finding. The connections with capability roadmaps also need to be made explicit within the report body. Dr. Greene added that the report should note the technology demonstration role of missions for science and exploration objectives other than planet-finding. Rich Capps, the Advanced Planning and Integration Office (APIO) coordinator for this committee, said he had additional input from other SRM committees on their perceived connections with the primary missions in this roadmap. Dr. Burrows said that a coherent case should be stated for the technology development needed for the roadmap missions.

The APIO still favors placing the roadmap's discussion on education and public outreach (E/PO) in an appendix, Dr. Burrows said, and placement of the E/PO discussions is an issue for the committee to address. For the coverage of external partnerships (beyond NASA) in Appendix 5, Dr. Burrows said that specific connections to international efforts, particularly Canadian-led missions, need to be identified and emphasized.

Dr. Burrows next asked for additional general comments from the members on the current draft of the roadmap report. Dr. Weinberger said that the draft now reads like a committee-written product, and the committee agreed that structural work and rewriting for coherence of message and presentation is needed. Dr. Martin suggested that the current sections 3 and 4 need to be knit together as an integrated story, even if they remain separate sections. Dr. Spergel asked the members to think about what is missing from each section as currently drafted: what has not been addressed that should be. Ms. Heath said that the current draft is too long and suggested cutting it by 30 percent. Also, the activities by international entities, as well as linkages to other NASA strategic roadmaps, need to be reflected in branch points of the roadmap. Dr. Marcy suggested that one member work on making the entire document coherent in message and presentation. The relative technological readiness of the Terrestrial Planet Finder–Coronagraph (TPF-C) and Terrestrial Planet Finder–Interferometer (TPF-I) missions should be discussed. He also asked if the roadmap should incorporate or reference any of the white papers distributed by Dr. Smith from the NASA Request for Information (RFI) on implementation of the strategic objectives.

Dr. Spergel said that the roadmap should discuss the relationship among SIM, TPF-C, and TPF-I as complementary missions, rather than simply as seriatim missions. The case for SIM improving the efficiency of TPF-C needs to be stronger, and the fundamental importance of mass measurements to overall planet-finding objectives should be stated. For the April 15 presentation to the NRC, the format calls for specific objectives to be accomplished by the roadmap, as milestones to achieving the strategic objective for which the roadmap was developed. Dr. Spergel gave his list of five draft objectives for the committee's consideration:

- Understand how star formation leads to planet formation.
- Determine the frequency of Earth-like planets.
- Determine the spectra of Earth-like planets.
- Characterize Earth-like planets.
- Detect signs of life.

Dr. Greene said the science discussion in section 2 needs a paragraph or a few sentences to make a coherent case for planet formation and habitability science as contributing to the strategic objective. Section 3 needs to state how the science objectives, including planet formation and habitability, are met by the mission set presented. Dr. Weinberger added that the current mission descriptions for TPF-C and TPF-I are missing their capabilities to investigate planet formation.

The committee discussed how to strengthen the story line for planet formation and habitability and how to link it with the main planet-finding story line.

Dr. Tyson agreed that the draft needs to be tightened up by trimming. Connections with industry are missing in the current draft, and making such connections will help to sustain the effort.

Dr. Mather said he had the same concerns as Drs. Weinberger and Greene about strengthening the story line for planet formation and habitability. There are still concerns in the community, he said, about making TPF into two missions. Dr. Spergel added that the committee should think about which arguments on TPF are most germane for the audience to which this document is addressed. Dr. Smith said the ultimate audience for the roadmap report is NASA Headquarters and the Synthesis Team working on the ISA. The ISA will be the product distributed to the public. This point led to discussion among the committee and staff on reasons for also writing the roadmap document for audiences other than the Integration and Synthesis Teams constructing the ISA.

Dr. Weinberger noted that the draft does not yet discuss the role of giant planets in understanding planet formation and habitability. The committee discussed how to incorporate the science of giant planets without detracting from the most compelling story line for public acceptance and support. Dr. Spergel agreed with a comment that comparative planetology should be mentioned somewhere in the set of science objectives. He said that the area of science underlying the search for Earth-like planets is comparative planetology.

Victoria Meadows suggested that redundancies between sections 2 and 3 could be addressed by tightening section 3 to just the recommendations, after incorporating science-related material from it into section 2 as needed. Habitability should be addressed in the context of comparative planetology, and she suggested that the overall objective be explained in terms of finding planets that are detectable as habitable, rather than just finding habitable planets. With respect to detectability of habitable bodies, the committee discussed science results that could increase the importance of investigating satellites of distant giant planets (by analogy with Europa and Titan).

Dr. Mather asked if the roadmap report should address the technological feasibility of the capability required for the TPF mission objectives. This led the committee to discuss where in the report to put detailed arguments such as this and how to make the best case for TPF-C feasibility. According to a staff comment, integrated modeling during the pre-phase A work for TPF-C is being used to support its technological feasibility. The committee and staff discussed the extent to which the CRMs will support the technological readiness for TPF-C and the value of achieving the necessary Technology Readiness Level (TRL) for key technologies essential to the main missions in the roadmap. Dr. Tyson said that comments made at other SRM Committee meetings have implied a conflict between scientists and technologists on whether science objectives should drive technology development. There can also be a technology push from capabilities driven by interests other than science, he said, and it is therefore a two-way street.

Format for April 15 Interim Report

Dr. Spergel led the committee's review of APIO requirements and guidance for the April 15 presentation and the final roadmap report. The discussion of the terms of reference for the NRC panel review led to discussion of how the roadmap time lines should be constructed. Other topics discussed were funding assumptions for this roadmap, how to identify top-level opportunities that cut across the strategic roadmaps, and incorporation of priorities from the NRC Decadal Surveys.

The committee discussed and rephrased the specific roadmap objectives as proposed by Dr. Spergel. A slide for the April 15 presentation on the current status of planet-finding science was drafted. The committee discussed the relationship of the major planet-finding missions to these objectives and how the missions relate to each other. There was general agreement that these are key points on which further discussion is needed. The draft slides presented the Search for Earth-Like Planets in three temporal phases: near term (2005–2015), mid term (2015–2025), and long term (beyond 2025). The committee discussed how positive near-term results in identifying a planet target might focus resources on observing that target sooner than planned and how to represent such possibilities as branch points in the roadmap. For the long-term phase, the committee discussed whether a large optical to ultraviolet (optical-UV) imager should be included in the roadmap and how a planet-imaging mission should be characterized. A capability to resolve 1 AU in the optical-UV at 150 parsecs, using long-baseline optical interferometry in space, could provide a major stepping stone to planet imaging. Another potential long-term mission discussed was a moon-finder mission (to detect moons around terrestrial planets).

The committee discussed how technology requirements for the Search for Earth-Like Planets SRM should be presented in the April 15 presentation. Also discussed were mechanisms for providing the technology research and development (R&D) to support both near- and long-term mission requirements. The staff and committee discussed the role of space science missions as drivers for beginning and sustaining technology development. Dr. Mather noted that a budget for general technology R&D is hard to defend because it lacks commitment to an outcome. Successful technology R&D, he suggested, needs to be located, at the least, within a mission study office, as was done with JWST. After discussion, there was general agreement that capabilities should be called for in the roadmap, rather than specific technologies, to allow for competition and emergence of new advances (such as the advances in coronagraphy that led to formulation of TPF-C). The committee also discussed the need to sustain human capital through post-secondary education, whereas the NASA Office of Education has focused on primary and secondary (K-12) education as feeding the front end of the pipeline for science and engineering. This session concluded with discussion of the format for the one-page graphical depiction of the roadmap.

Lunch Presentation on Informal Education and the Exploration Initiative

Dr. Tyson began his presentation with highlights of the resources and capabilities for informal education at the Rose Center/Hayden Planetarium. The American Museum of Natural History also has a formal academic structure equivalent to 12 academic departments. He then illustrated some of the media impacts of astrophysics discoveries and the public response to them. He used the public response to cancellation of the Hubble Space Telescope (HST) servicing mission as an example of the public "taking ownership of the cosmos." Dr. Tyson related this public appetite for space-related news to the context for the announcement of the *President's Vision for U.S. Space Exploration* in January 2004. The political aspects of the Exploration Initiative raise the question of how to sustain the effort over time. In the course of history, he said, the only three successful drivers for costly projects have been defense (e.g., the Great Wall of China), the promise of economic return (e.g., the voyages of discovery), or the praise of monarchial/divine power (e.g., the pyramids of Egypt). In this context, he discussed potential alignments of sociopolitical forces that could provide sustained support for the Exploration Initiative. He commented on misleading media statements critical of the report by the President's Commission on Implementation of United States Space Exploration Policy (Aldridge Commission), on which he served. Dr. Tyson concluded with comments on resource requirements, an approach to funding the Exploration Vision that would build on commercial interests, and the science potential of the Exploration Vision.

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Discussion: Dr. Tyson and other committee members discussed public reactions to the phase-out of the Shuttle and the International Space Station, as well as the public response to the science that will be enabled by the Exploration Initiative. He held that the investment in NASA science and technology can be justified by the economic and security advantages from increasing the interest of the next generation in scientific and technical careers. Dr. Burrows noted that the introduction of the roadmap should cite relevant portions of the Aldridge Commission report.

Mapping Existing Material into the April 15 Format, Key Roadmap Decision Points

After lunch, the committee returned to detailed consideration of the draft SRM report, the material from the draft to include in the April 15 presentation to the NRC, and key decision points to include in the roadmap as branch points connecting pathway options.

Dr. Spergel led the detailed discussion of the section 2 draft. Drs. Greene and Weinberger agreed to work on a high-level summary for section 2 of the relationship of roadmap missions to the science objectives of understanding planet formation and the context for habitability. Dr. Burrows said that the list of overarching science questions addressed in the roadmap should appear at the beginning of section 2. Major planning documents such as the Aldridge Commission report and the *President's Vision for U.S. Space Exploration* also should be called out early in section 2. On use of the term "origins" (previously used as shorthand for the Astronomical Search for Origins theme in the former Office of Space Science), Dr. Kinney recommended that the term could be retained but should be used without capitalization, as in "the origins, evolution, structure, and destiny of the universe." Dr. Spergel said that the committee should aim at writing to its mandated Strategic Objective, not to NASA's organizational structure. Dr. Smith reminded the committee that the roadmap should include explicit priorities. In response to a comment from Dr. Meadows, the committee discussed what TPF-I will contribute with respect to identification of atmospheric gases on detected planets. Detection will be photometric, not spectrographic. After discussion, the committee agreed on resolving the content overlap between sections 2 and 3 by moving the science basis for missions into section 2 and the summary of missions and investigations into section 4 (which will become the new section 3).

The committee next discussed decision points based on science results, to be included in section 4 (to become section 3). Science decision points discussed were small and large values of the frequency of occurrence of Earth-Like planets (η_{Earth}) and high levels of exozodiacal emissions at potential targets, based on findings from Kepler and the Keck Interferometer. After discussion of the effect on pathways of a mission failure in the early missions, the committee agreed that the text should state clearly that loss of one mission does not change the mission set but would extend the time line. Committee members and staff discussed how the relationship between SIM and TPF-C would change if the frequency of Earth-like planets were either much smaller or larger than anticipated . The committee agreed that the strongest case for SIM is the astrophysics it will investigate, rather than the improvement in efficiency for TPF-C. Dr. Meadows said that the strength of TPF-C is more in its characterization of planet-targets than in finding (detecting) planets. The committee discussed what happens if η_{Earth} is found to be large (greater than 1). One option in this case would be to maintain a funding wedge for smaller competed missions to handle the increased observing opportunity.

Dr. Tyson suggested that the draft needs more emphasis on the science story, less on a specific mission set. He thought that a strong science story would endure longer than a capability-based approach. Dr. Spergel agreed that section 2 should provide the compelling science argument. Section 3 should be the mission set. Next, the committee discussed the effect on the pathway if

the exozodiacal emissions for planet-candidates are high. (The Keck Interferometer and the Large Binocular Telescope Interferometer (LBTI) will provide measures of the exozodiacal emissions around target stars.) A larger aperture might be appropriate for TPF-C in this case, but SIM would be unaffected. Dr. Spergel and Dr. Michael Devirian agreed to update the draft section on decision points. The draft section on milestones will also be updated. Dr. Tyson agreed to review the draft of the report body after Dr. Spergel incorporates the revisions due from other members. The members agreed to turn in all of their drafting assignments by Monday, April 4.

Public Input Session

The committee heard presentations from three members of the public who had requested an opportunity to address the committee.

Sally Heap of Goddard Space Flight Center (GSFC) addressed the committee on "The Roles of SIM, TPF-C, and TPF-I in Searching for Earth-Like Planets." She began with reasons why the TPF missions are essential to planet finding. She compared SIM's planet detection capability with the TPF missions for a habitable zone defined as extending out from a host star at 0.1 to 10 AU and for planet masses from 0.1 to 10 or 20 Earth masses. Her conclusion was that TPF-C and TPF-I can cover the habitable zone of many target stars of potential interest, whereas SIM cannot. SIM's capability for planet detection is strongest in the outer portion of the habitable zone; TPF-C's relative strength is in the inner habitable zone. As the observing distance increases beyond the nearby stars used in Dr. Heap's illustration, the fraction of the habitable zone in which planets can be detected decreases. Dr. Heap discussed with the committee the capability of extracting mass data from the SIM database, based on TPF finding a target of interest not analyzed during the original SIM census. Dr. Marcy noted that the limits of detectability used in Dr. Heap's example were at a false positive rate of less than 1 percent. At a 5 percent false positive rate, for example, the detectability space (in habitable zone coverage and planet mass range) is about doubled. The discussion led to agreement on the value of having data from both SIM and TPF missions, as well as having temporal overlap of the SIM and TPF-C missions, to provide reliable confirmation of Earth-like planet detections. The number of target stars that TPF-C can investigate is largely a function of the time required for its spectroscopic observation.

David Bennett of the University of Notre Dame addressed the committee on "Terrestrial Planets and Dark Energy with a wide FOV Space Telescope." He described a proposed mission concept called the "Microlensing Planet Finder" (MPF). MPF would complement the Kepler mission by detecting planets by their mass rather than area. Comparing the sensitivity of Kepler and MPF, Dr. Bennett said that MPF would be more sensitive at orbital distances greater than 1 AU. The target field for an MPF mission is the galactic bulge because a high density of source and lens stars is better for the microlensing technique. Dr. Bennett compared the MPF design with the designs of two other dark energy probes: the Supernova/Acceleration Probe (SNAP) and Destiny. He discussed the possibility of performing both planet-finding and dark energy investigations with the same mission. Although the two objectives would compete somewhat for observing time, the preferred observing schedules would mesh well. Because η_{Earth} (for planet finding) and the differences between high and low redshift supernovae (for the dark energy mission) are both uncertain at present, Dr. Bennett suggested that the ultimate division of observing time between the two objectives could be decided by scientific urgency. The longer primary mission time and the requirement for an aft Sun shield to accomplish both objectives would increase the cost of MPF. Dr. Bennett estimated a cost of $700 million for a joint mission, compared with a cost of $600 million for JDEM and $400 million for a separate microlensing planet-finder mission. He suggested that opting for a joint mission could improve the chances of funding JDEM. In the past, he said, the two science goals fell in different themes within the Office of Space Science, making

it difficult to weigh the benefits of doing both with one mission. In response to a question from Dr. Kinney, Dr. Bennett said that the proponents of the SNAP concept in the DOE have been cooperative, but the planet-finding goal is not viewed as relevant to the DOE's science objectives.

David Leisawitz, also from the GSFC, addressed the committee on his proposal for achieving high angular resolution in the far-infrared (far-IR) with a concept called the Space Infrared Interferometric Telescope (SPIRIT). He noted that the *Community Plan for Far IR/Submillimeter Space Astronomy* includes SPIRIT as a future mission between the Single Aperture Far-IR Telescope (SAFIR) and the Submillimeter Probe of the Evolution of Cosmic Structure (SPECS). Key science questions that SPIRIT could investigate include how planetary systems form and how some planets acquire components for life. Dr. Leisawitz contended that these questions will remain unsettled until we can image representative samples of proto-planetary disks and debris disks. He gave reasons why the far-IR is the best spectral region for observing objects in protoplanetary disks. Based on the distance (140 parsecs) to low-mass star-forming regions with many debris disks and the size of the disks (about 10 AU), an angular resolution of 70 milliarcseconds is needed. This resolution, which is a hundred times better than the Spitzer Space Telescope observing at 24 μm, would require a mirror 85 m in diameter on a single-aperture telescope. The SPIRIT concept instead uses a pair of cryocooled 1 m telescopes with a 40 m maximum baseline. The Origins Probe study of SPIRIT developed the science case, an engineering design, and cost estimation and validation studies. SPIRIT would complement JWST and ALMA, Dr. Leisawitz said, by filling in the observing range between them. It could provide measures of exozodiacal emissions for planetary systems and is also important as a technology precursor for missions such as TPF-I, SAFIR, JWST, Constellation X, and SPECS. Dr. Leisawitz suggested that, if SAFIR is not affordable until 2020, SPIRIT, which would be a probe-class mission, could be flown as early as 2015. He recommended that the committee add a probe-class, far-IR spatial-spectral interferometer, or at least the corresponding planet-formation science and capability requirements, to the Search for Earth-Like Planets SRM.

Questions. In response to Dr. Burrows' question on relative capability of SPIRIT and SPECS, Dr. Leisawitz said that SPECS provides Hubble-class angular resolution, but is farther out in time. SPIRIT would be a pathfinder mission with respect to both the science and technology for SPECS. Dr. Spergel asked what SPIRIT could do that could not be done with ALMA. Dr. Leisawitz does not believe that ALMA will be able to observe as far into the submillimeter region as has been claimed. SPIRIT can observe spectroscopic lines for water that ALMA cannot, as well as observing hydrogen lines that ALMA cannot observe without ambiguity. Hydrogen concentrations are important, he said, for understanding the shape of a stellar disk.

Vision Mission and Origin Probes Placement in the Roadmap

The committee discussed the concept studies for Origins Probes in the context of continuing the morning's discussion of the potential role for a competed mission line directed to science goals, including planet-finding, of the Universe Division. Because the ratio of Explorer proposals submitted to proposals accepted is 13 to 1, the effort to prepare a competitive Explorer proposals is large relative to the chance of winning. The Universe SRM Committee has therefore suggested that the community would be better served if each Explorer Announcement of Opportunity (AO) were directed toward a science goal (or several goals) specified in the AO.

Members of the Search for Earth-Like Planets SRM Committee asked if the number of selectable (highly rated) proposals in response to the latest AO was sufficient to justify narrowing the scope as suggested by the Universe SRM Committee. Dr. Kinney replied that a number of the other proposals had done well in the science evaluation but were judged to be at high risk of exceeding

the Explorer cost cap. In response to a question from Dr. Burrows, Dr. Kinney said another option might be to divide the Explorer budget line between the Earth-Sun System Division and the Universe Division. The members and staff discussed the impact of increasing the interval between medium-class Explorer (MIDEX) AOs and the frequency with which probe-class missions might be possible with a separate competed line directed to Universe Division science. Members expressed concern about providing sufficient mission options to sustain the science community and support the post-graduate education and maturation of new investigators. Members and staff also discussed the impact of funding a new competed line on the budget profiles for strategic missions, given that the overall budget for the division is unlikely to increase above the rate of inflation. Dr. Kinney agreed to develop some budget scenarios for the SRM Committee by April 11.

Dr. Greene said that the increased margins for risk and the increase cost of launch vehicles has meant that the amount of science done with each MIDEX mission is less than in the past. With respect to targeted versus open-ended solicitations, he agreed that larger missions such as Origins Probes and Einstein Probes need to have community support for the mission content. To build this support, he favors a targeted solicitation. However, there also should be opportunities to respond quickly to good ideas proposed in open competition. Dr. Spergel said that missions planned far in advance with community buy-in become more like strategic missions, with little capability for flexible response. Dr. Martin said that the community cannot be protected through providing sufficient mission opportunities. There are not sufficient funds or launch opportunities to do that. Instead, technology development programs and smaller investigation options such as balloons, suborbital rockets, and shuttle payloads are necessary to sustain the community. Dr. Burrows and Dr. Spergel framed the issue for the committee's response in terms of whether members were willing to delay the TPF missions to support a competed line for Origins Probes. Subsequent discussion topics included using smaller missions as technology pathfinders for the strategic missions, issues in relying on just a few major flagship missions, the need for a mission class larger than MIDEX, and the value of having some open opportunities to take advantage of unanticipated science results, such as η_{Earth} being large.

- Dr Weinberger favored a line for smaller missions because of the positive impact on the community, compared with having just one strategic mission in planet finding every 10 years.
- Dr. Meadows favored the competed line for smaller missions both for taking advantage of science opportunities and for building the community.
- Dr. Marcy asked if TPF-C is likely to face technical issues that might be better tested with a small system in space, rather than through laboratory work alone. Dr. Spergel replied that the principal feasibility questions are tied to the size of TPF-C, such as implications for thermal and mechanical problems. (Smaller-scale implementations have limited value in resolving these scaling issues.)

The members and staff discussed the relative benefits and costs of small missions as technology demonstrations and pathfinders, compared with laboratory studies and simulations to retire technical risks associated with major advances in strategic missions. Dr. Burrows summarized the discussion as indicating support for a competed line directed to Universe Division science, but the committee would not want it to jeopardize the main line of planet-finding missions. Dr. Spergel agreed to draft a strawman paragraph summarizing the reasons for adding such a line to the division's budget. The committee can then consider costs and the trades against the rest of the program before deciding whether to accept a competed-line option. With respect to characterizing how a competed line might be directed, there was general agreement that a justification for it

should use a contingent list of potential opportunities but not lock in on specific missions (as was done with the Einstein Probes in the Beyond Einstein roadmap).

First-Day Wrap-Up and Overnight Assignments

Dr. Burrows asked how the roadmap should address the issue of TPF-C doing ancillary science (to its primary planet-finding objective) with its 8 m optical telescope. TPF-C can be more strongly defended by noting its capabilities to accomplish a variety of science objectives without compromising its primary objectives. Dr. Weinberger asked if the study of protoplanetary disks falls within planet finding or counts as ancillary science. The committee discussed TPF-C time allocations for planet-finding and other uses. The potential for ancillary uses of TPF-C can be emphasized in the roadmap section on inter-roadmap dependencies.

Dr. Burrows asked the members to think overnight about the Vision Missions (e.g., SAFIR, SPIRIT, a life-finder mission) and their potential role in the roadmap. Also, should the roadmap discuss the general concept of doing "vision mission" concept studies, including the possibility of doing additional studies beyond the last set selected for awards? After reviewing the work to be done on the second day of the meeting, Dr. Burrows adjourned the meeting until the next morning.

Wednesday, March 30, 2005

At the opening of the Wednesday session, Dr. Smith announced that Ghassem Asrar, the third committee co-chair, would be unable to attend as planned because of illness. The day began with the presentations on SIM. Maureen Heath recused herself from participation for the duration of the presentation and discussion of the SIM redesign process.

SIM Baseline Design Process

David Gallagher from the SIM redesign team at JPL briefed the committee on the SIM redesign. The redesign began with a letter from Anne Kinney on January 21, 2005, stating that NASA could not afford the current SIM mission concept, which also had inadequate mass and power margins. A redesign team was established. To rescope the mission, the team was allowed to treat the SIM Level 1 requirements as goals, rather than requirements. Each of the two mission options requested must include a 30 percent cost reserve and sufficient technical margins. The redesign must also demonstrate the scientific uniqueness of the mission, continue to support the Exploration Vision goal of conducting advanced telescope searches for Earth-Like planets and habitable environments, and be useful in enhancing the science return of TPF. Mr. Gallagher summarized the redesign work flow that will lead up to a preliminary design review and non-advocate review around the end of July 2005. The redesign will subsequently be reviewed by the NAS/NRC Committee on Astronomy and Astrophysics. Northrop Grumman Space Technology, the industry partner, has made a significant contribution to the redesign.

The candidate redesign architecture for SIM has three interferometers rather than the four in the original design, a 9 m baseline rather than 10 m, and optics approximately 25 cm in diameter rather than 50 cm. Narrow angle performance will provide 1.44 microarcsecond resolution or better. Wide angle performance will be 6.0 microarcseconds or better. The optimization trades by the redesign team have maintained significant margins in mass, power, and cost. There will now be two guide interferometers and one science interferometer, rather than two of each. Launch is projected for August 2010.

Dr. Michael Shao from JPL described the science aspects of the SIM redesign. The project and science team assessed the performance of redesign Option 1A and agreed that all or most key SIM projects can be reoptimzed to minimize the science impact with only modest decreases in precision or sample size. The team judged that the science from the redesigned SIM would still be compelling. However, narrow angle astrometry for faint objects is substantially affected, with resolution for magnitude 13 objects now reduced to 3.7 microarcseconds from 0.86 microarcseconds in the old design. In response to a question from Dr. Martin, Dr. Shao and NASA staff explained the relation of the redesign performance specifications to the SIM performance goals reviewed and accepted by NAS/NRC review committees in the past. Dr. Shao then reviewed how SIM results will complement and enhance the TPF imaging missions in detecting and confirming terrestrial planets. SIM astrometry will provide estimates of the mass of candidate planets, plus the inclination and eccentricity of their orbits. It will also improve the TPF imaging search by providing TPF with data on where to observe a planet around a candidate star. Using simulated SIM searches for a reasonable distribution of planetary systems around stars in SIM's range, Dr. Shao described how even a false alarm probability of 10 percent in the SIM results would be useful in enriching the search sample for TPF. Determining that a terrestrial planet has been detected from SIM data alone requires a much higher degree of confidence (a false alarm probability of 1 percent or less). In his hypothetical example of SIM and TPF-C detections, SIM would enrich the planet-finding success of TPF-C by a factor of 2.6. Because of conservatism in estimating performance of the original design, Dr. Shao said, the redesign is in fact roughly consistent with the performance goals of the original SIM AO. The science team has also urged the redesign team to examine ways to improve on the baseline and aperture of the redesign, as these parameters will greatly influence the science capability.

Questions: In response to a question from Dr. Burrows on the impact of the loss of resolution for faint objects, Dr. Shao estimated that a third of the observing program is photon-limited and therefore would be affected by the reduced capability for narrow angle observing. The number of faint targets that can be imaged within a given observing time will be about half that in the old design. Dr. Burrows said that the committee will need to include the SIM redesign options in its roadmap, as NASA's decision on SIM will not occur before the roadmap deliverable is due. Dr. Shao answered questions on the extent of SIM data on planetary orbits that can be anticipated and how the precision in that data will affect the guidance SIM can provide to TPF-C. Although a few of SIM's 200 target planets will have periods greater than 5 years, the majority will have completed a full orbit within SIM's mission lifetime, allowing relatively precise orbital data to be passed to TPF.

Advanced Telescopes and Observatories Capability Roadmap Input to the NRC

Lee Feinberg of NASA GSFC—and co-chair of the Advanced Telescopes and Observatories Capability Roadmap Team—spoke to the committee by telephone. He was joined by Philip Stahl and James Fienup, also members of the roadmap team. The CRM teams will provide each of the SRM committees with a 1–2 page summary matrix of capabilities technologies that are called out in the capability roadmap and pertain to that SRM. The team told the NRC review team that it expects a further iteration will be needed on the reference mission set and mission dates used in the capability roadmap.

At Dr. Feinberg's request, the CRM reference missions relevant to the Search for Earth-Like Planets Strategic Roadmap and their approximate dates were compared with the missions being considered for the strategic roadmap. The CRM team has included a far-IR space interferometer mission, with capability like that of the proposed SPIRIT concept, as a stepping-stone to the SPECS mission in the long term. Other mission concepts included in the Origin Probes studies

were discussed as well. Dr. Feinberg said the CRM team foresees a need for cost-effective construction of space-based telescopes with 3 m apertures. In answer to Dr. Burrows' question on assembly and servicing of observatories at the L2 libration point, Dr. Feinberg said the CRM team thought those capabilities could be cost-effective if they were leveraged from other exploration-oriented capabilities such as highly capable construction and servicing robots. Dr. Feinberg noted that the capabilities included in the CRM roadmap are typically timed to be ready 5 years before the launch of the first mission that will use them. For SAFIR, however, the technology lead-time is just 4 years, and its feasibility assumes substantial leveraging from other Exploration Initiative developments.

A major conclusion by the CRM team was that complex space telescopes may benefit from servicing and assembly robotics. This and other leveraging opportunities, including a new heavy-lift launch vehicle, need to be explored. The team found that optics and wavefront sensing are critically enabling technologies for many missions in both the near and far term. Distributed and advanced spacecraft capabilities, including formation flying, will be a major need in the longer term but not for near-term missions. However, work on the enabling technology should start now to be ready when it is needed. The team also commented on specific facility requirements to support technology development for reference missions, including TPF-C and SAFIR. Because many of the space-based systems will be distributed architectures, they cannot be fully tested on the ground. Therefore, advanced modeling and simulation capability will be essential for technical risk reduction, starting with testing for JWST. The team also identified some key possibilities for NASA to partner with DOD and the National Reconnaissance Office—for example, on low-cost, 3-meter class telescopes.

Discussion: Dr. Greene asked if the CRM specifies when technology development should start for capabilities like the cryocoolers on SAFIR. Dr. Feinberg reviewed the portion of the roadmap detailing cryocooler technology. Dr. Burrows asked whether a pathfinder version of the cooler technology needed for TPF-C had been considered by the CRM team. Dr. Feinberg replied that such a mission had not been in the reference set given to the team, but the team could address it in its next round, if it is in the Search for Earth-Like Planets SRM. To illustrate the way that mission options would be addressed in the SRM, Dr. Burrows explained to the CRM team members the decision point and pathway branch structure that will be used. Dr. Feinberg noted some technology readiness branch points that the SRM Committee might consider including in the roadmap. Dr. Feinberg discussed the CRM team's conclusion that advanced modeling, laboratory testing, and other ground-based technology risk reduction activities are often more cost-effective than attempting a technology demonstration or pathfinder mission. The difficulties in the New Millennium program were a major factor in this conclusion.

In response to Dr. Weinberger's question on active and passive cooling as a critical technology for TPF-I, Dr. Feinberg replied that the technology would be needed for prior missions. Therefore, it is not addressed explicitly in the CRM as a TPF-I issue. There are some aspects of the TPF-I heat baffle system that should be added to the CRM. Dr. Mather responded to a question from Dr. Meadows on active cooling of the TPF-C spacecraft. He said that the JWST team found that thermal isolation of the instruments from the electronics, which need to be warmer, is the key factor. SRM Committee members and Dr. Feinberg discussed passive and active cooling requirements for TPF-I optics and instruments. Dr. Burrows asked if the CRM team had considered improved mirror coatings for TPF-C that would allow it to accommodate instruments observing at shorter wavelengths (in the UV) without compromising capability in the principal wavelength region for the planet-finding mission. The CRM team had discussed this issue with the TPF-C team, and uniformity of the coating appears to be a much more difficult technology challenge. The CRM team members on the call described the technology

requirements related to mirror coatings that are covered in the CRM. For TPF-C specifically, Dr. Feinberg said the known coating alternatives would limit the capability for the primary planet-finding mission.

Dr. Feinberg asked when the SRM Committee would have a product that his CRM team could use as input to the next round of revisions. Dr. Burrows and Dr. Smith said that the viewchart presentation for the NAS/NRC review panel would be available as an official product of the SRM Committee on April 15, with the full written report available by June 1. Dr. Smith asked the SRM Committee to consider whether the timelines assumed in the CRM matched with the phasing of missions that would be used in the Search for Earth-Like Planets Strategic Roadmap. At the level of the 10-year phases for the near, mid, and far term missions, there were no discrepancies with the CRM. In response to Dr. Feinberg, Dr. Burrows said that sequences and dependencies across missions will be detailed in the strategic roadmap. The approximate year dates being used by the CRM team and the SRM Committee are not in conflict. After a discussion of the approximate dating for mid-term and far-term missions, Dr. Mather asked the CRM team members if the capabilities for Life Finder and Planet Imager science goals are too far out to be included credibly in the roadmap. The answer was that a Life Finder mission seems to require robotic assembly of segments for a 25 m telescope. The CRM team assumed that Life Finder would require multiple 25 m telescopes flying in formation. Although a technology readiness date of 2020 is ambitious for this capability, it is not impossible. The capability development for formation flying of large telescope spacecraft was discussed. In particular, TPF-I would be a precursor for Life Finder formation flying. The SRM Committee and the CRM team members agreed that the Life Finder and Planet Imager concepts are not yet defined clearly enough for detailed planning in either the SRM or the CRM.

Dr. Greene asked how the strategic planning process would ensure that technology development begins in time to provide capabilities required for planned. missions. Dr. Smith explained that the Integration Team is supposed to examine the capability time lines, based on the CRM content, in light of the mission time lines from the strategic roadmaps. Dr. Burrows said that these technology requirements, in the context of the Search for Earth-Like Planets SRM, should be addressed in Section A of Appendix 3.

Critical Inter-Roadmap Dependencies

The committee began its consideration of dependencies across SRMs with the template table for such dependencies included in Appendix 4 of the current roadmap draft. Rich Capps explained the report requirement from APIO and the format for identifying roadmaps and potential dependencies between them. He then reviewed the list of linkages to this roadmap that have been stated by other SRM Committees. The committee discussed linkages defined by the Robotic and Human Exploration of Mars SRM Committee and agreed that there is a connection between the roadmaps on expanded science of biosignatures. The committee did not agree with the Solar System Exploration SRM Committee that work on expanding the habitable zone to satellites of giant planets would affect the detection strategy for Earth-like planets. No dependencies were identified with the International Space Station (ISS), Shuttle, or Aeronautics SRMs. Connections with the Universe SRM include the science of star formation and disk formation, as well as common observational strategies. The committee agreed that the general astrophysics capabilities of TPF-C should be highlighted in this section. Science and capability linkages with the "origins" elements of the Universe roadmap were discussed. With respect to the Earth Sciences SRM, the committee agreed that understanding the Earth as a model for extrasolar planets was a connection. Habitability parameters related to planet–star interactions are a common element with the Sun–Earth System SRM. There will be strong interconnections with the E/PO SRM. As a

potential connection with the Nuclear Systems SRM, the committee discussed reasons for eventual use of nuclear-based power and propulsion for far-term missions, such as IR observatories located at greater than 3 AU from the Sun.

The committee agreed with a staff suggestion that Gary Blackwood and Rich Capps will draft a section for the roadmap report on dependencies of the Search for Earth-Like Planets SRM on the CRMs. A dependency on the high-energy propulsion CRM is thruster technology for formation flying. No dependencies were identified for the in-space transportation CRM. There will be important dependencies on capabilities in each of the subteam areas within the advanced telescopes and observatories CRM. When the communications and navigation CRM was discussed, the committee was not certain that there will be a data rate driver from any of the planet-finding missions. Even the engineering checkout phase of future missions is unlikely to be more data-intensive than the checkout phase for the Spitzer Space Telescope. Some of the capabilities in the autonomous systems, robotics, and computing systems CRM would enhance long-term planet-finding missions but are not required. No near-term requirements for that CRM were identified. Dependencies on scientific instruments and sensors include instrument cooling and ancillary instruments for the SAFIR and TPF missions. No critical dependencies were identified for the robotic access to planetary surfaces CRM, the human capabilities CRM, the transformational spaceport/range CRM, the in situ resource utilization (ISRU) CRM, or the nanotechnology CRM. Mr. Capps and the committee discussed whether modeling to support space-based observing systems too large for ground test facilities would be included in the advanced modeling, simulation, and analysis CRM. Dr. Burrows suggested that global circulation models (GCMs) for terrestrial planets with atmospheres was another dependency in this capability area. There is a general connection to the systems engineering and cost/risk analysis CRM for mission planning and development

After a discussion of how the strategic roadmap might be affected by closure of specific NASA Centers or major facilities, the committee agreed to state which capabilities at ground facilities are needed to get the science results from the roadmap missions, rather than naming particular centers or facilities. Areas in which facility capabilities are needed include laboratory astrophysics, other laboratory and field work, theoretical modeling, and supercomputing.

External Partnerships—Engaging the Nation and the World

The committee next reviewed the existing draft material for section VII on external partnerships. Missions with international participation to be mentioned in this section include JWST, Herschel, SOFIA, and TPF-I/Darwin. Dr. Greene agreed to draft text on Herschel and SOFIA for this section. Material will be added on international contributions to JWST. The committee discussed and agreed to revise the existing material on the context and purposes for international cooperation.

To include a role for partnering with industry, Ms. Heath suggested that generic, recurring problems in cost and schedule growth could be addressed if mission requirements were developed and maintained in the context of total systems engineering. Dr. Martin agreed and added that the current acquisition and requirements development process allows requirements to grow beyond a mission or program's budget envelope. Members discussed whether systems engineering for NASA-like projects is done more successfully in other Federal agencies. They also discussed the impact of the political environment on sustaining systems engineering discipline.

Plan for the April 15 Product

Dr. Burrows asked the section leads to ensure that their section drafts are self-contained and coherent before sending them to Dr. Spergel and him by Monday, April 4. Dr. Spergel will use the section drafts to prepare the draft for the April 15 presentation. The committee discussed the format and level of detail for the time line overview of all missions and investigations to be recommended in the roadmap. A version of this graphical representation will be needed for the April 15 product.

Science Integration Process

Dr. Smith presented the briefing slides prepared by Dr. Paul Hertz, the Assistant Associate Administrator for Science in the SMD, on the process for integrating the nine SRMs being led by the SMD. The objectives of this intermediate step in roadmap integration are to identify explicit constraints on the ISA, identify a core mission set drawn from the strategic roadmaps, and create an integrated science story and science strategy for NASA. A team of NASA system scientists from Headquarters and the Centers will review the roadmap drafts for dependencies not recognized by the SRM committees in their reports. High-priority science activities for NASA are defined for this integration as (1) science that is enabled by exploration, (2) science that is fundamental and transformative, and (3) science that is required in service to support other objectives (e.g., exploration, climate change, other Federal agencies, etc.). Dr. Smith reviewed the planning schedule for the integration process, which includes a synthesis workshop in mid/late May and a review of the integrated science module by the NASA Science Advisory Committee (NSAC, successor to the SScAC) at its summer meeting during the last week of July. The SRM Committee members suggested that there be a mechanism for communicating the final ISA to the science community. The committee also discussed holding a third meeting before the June 1 draft roadmap report is delivered to the NRC for review. Although a formal teleconference may be used for the meeting, the dates of May 16–17 will be reserved by members in case a physical meeting is needed.

Technological Capabilities

The committee reviewed the current draft for Appendix 3, Capabilities Mapped to Stages/Pathways and Decision Points. Additional material will be added to the JWST discussion in the technology section, and specific mention will be made of those CRMs relevant to TPF-C and TPF-I. Dr. Mather will add material on long-term missions observing in the far-IR, including SAFIR and a far-IR spatial/spectral interferometer, and in the UV-optical region. SOFIA will be mentioned as a platform for demonstrating advanced technology for the long-term missions. The committee was satisfied with the story line in the section on technology readiness for TPF-C and TPF-I. Dr. Mather will check that the dates used in the SRM are consistent with dates in the advanced telescopes and observatories CRM.

The committee agreed to reorganize and rewrite the sections on external industrial and academic capacities. Drs. Greene, Meadows, and Weinberger will provide Dr. Mather with a list of critical scientific and technological capabilities to be supported. The text on NASA human capital, which will be drafted by Edna DeVore, will be included in this section. Dr. Mather will include mention of the capability enhancement possible if space-based observatories can be serviced robotically or by joint human–robot teams. Dr. Burrows said that this section will become the last section of the report body before the appendices.

In the review of section V on the national policy framework supporting the strategic objective and the roadmap, the committee agreed that appropriate passages from the key documents should be

quoted. Topics to cover include the NASA Strategic Goals, NASA Mission Statement, and the NAS/NRC Decadal Survey. The goal of inspiring the next generation of explorers should be quoted from the NASA Mission Statement.

The committee discussed where and how to mention relevant ground-based astronomy for planet-finding supported by the National Science Foundation. This led to a general discussion of the relevance of other research on detecting rocky planets at less than 1 AU from the host star.

E/PO Section

Ms. DeVore. reviewed the NASA Strategic Objective for E/PO and the themes in the draft material for the E/PO Strategic Roadmap. The NASA Office of Education is thinking about ways of sustaining public engagement over the long term. Committee members and staff discussed how best to express the public's interest in searching for Earth-like planets, in light of the challenges in maintaining public support for space exploration goals over an extended period. Ms. DeVore and the committee discussed whether the E/PO appendix should be written to be a stand-alone piece, which can be incorporated directly into the E/PO roadmap, or whether it should be written to build on but not overlap with material already included elsewhere in the report. They agreed that linkage between the roadmap objectives and the venues and opportunities for informal education should be added to the E/PO discussion in the Search for Earth-Like Planets SRM.

Neil Tyson, joining the meeting by telephone, offered comments on E/PO in space science. He favored integrating the education aspects with the science text in section 2. The public appeal of finding other planets like Earth should be used, he said. He suggested incorporating references to past public response to media announcements of planet-related discoveries in the science argument of the roadmap. The committee agreed with his suggestion to include details on how to build E/PO activities related to the search for Earth-like planets in an appendix on E/PO. Dr. Tyson agreed to review the draft document, after the next round of revision, for a coherent E/PO story.

White Paper Inputs to Strategic Roadmap

Dr. Smith led the discussion of the set of white papers received in response to a NASA Request for Information (RFI) on suggestions for future activities to support the Exploration Vision. In response to one paper, Dr. Marcy asked if the roadmap should include more about theory related to terrestrial planets. Drs. Greene and Meadows will draft material on the role of theory, including endorsement of the value to NASA planning of concept studies such as those done through the Vision Mission and Origins Probes grants. Next, the committee discussed a submission on free-flying occulting screens as a potential alternative to the observing techniques used by TPF-C and TPF-I. More generally, the members discussed whether the SRMs or the NASA program offices were a better mechanism for receiving and evaluating alternative technology options for the long-term mission pipeline. Dr. Smith will place on the committees document sharing website a set of charts prepared by the TPF Program Office on past calls for technology study proposals and the responses to those announcements.

Next Steps, Writing Assignments, and Schedule

Dr. Burrows reviewed the writing assignments for major sections and subsections of the roadmap report, using the section numbering in the current draft document. Dr. Spergel will continue as lead on section 2. As noted earlier in the meeting, the material in the old section 3 will be revised and rearranged, with science-related content merged with section 2 as needed and the mission descriptions added to the old section 4. Michael Devirian will continue as lead on old sections 4

and 6. Dr. Burrows will revise section 7. The capabilities appendix will move up to become the last section of report body. Dr. Mather will remain the lead for that section, and Dr. Burrows asked that it be sent to Mr. Chodil for review and comment. The lead for the appendix on inter-roadmap dependencies is Gary Blackwood, who will receive input from Rich Capps and Mr. Devirian. Ms. Heath will revise the section on external partnerships, incorporating material being drafted by others.

Public Input Session

Dr. David Bennett addressed the committee on the role of planet-finding in the Discovery Program. He suggested that the solar system science community is larger and better established relative to the extrasolar planet science community. Only 1 in 10 selected Discovery missions has been an extrasolar planet mission. To ensure that proposals for extrasolar planet missions receive a fair review in Discovery program solicitations, he asked that the SRM recommend that NASA take whatever steps it can to maximize the influence of scientific merit and minimize the influence of political pressure on Discovery selection.

The committee discussed issues in integrating elements of the planetary science, comparative planetology, and astrophysics communities that will be needed for a multidisciplinary approach to furthering the science underlying the search for Earth-like planets and understanding the context and conditions of their formation in the habitable zones of their host stars.

At the conclusion of the public input discussion, Dr. Smith adjourned the meeting.

Search for Earth-like Planets Strategic Roadmap Committee
March 29–30, 2005
Nassau Inn
Princeton, New Jersey

Agenda

Tuesday, March 29

8:30	Introductions and welcome, FACA reminders	(Smith)
8:45	Review of action items from the first meeting	(Burrows)
9:00	Proposed Strategic Roadmap outline/progress reports	(co-chairs)
10:30	Coffee	
10:45	April 15 interim report formats	(NASA HQ)
11:00	Mapping existing material into the April format	(co-chairs)
12:00	Lunch	
1:30	Key decision points in the roadmap	(Spergel)
3:00	Public Input session and/or Vision Mission/Origins Probe placement in the roadmap	
3:30	Coffee	
3:45	Review of scientific parameters for roadmap success	(Spergel)
5:00	Assign any overnight work for second day	(Burrows)
5:30	Adjourn	

Wednesday, March 30

8:00	Breakfast	
8:30	White paper inputs to Strategic Roadmap	(NASA)
9:00	Telescope Capability Roadmap input to NRC	(CRM Reps)
10:30	Coffee	
10:45	Plan for April 15 products	(Asrar)
12:00	Lunch	
1:30	Science Integration process	(NASA)
2:00	Public Input and/or Vision Mission/Origins Probe placement in the roadmap	
3:15	Coffee	
3:30	SIM baseline design progress	(TBD)
4:00	General discussion, next steps, writing assignments, schedule for completion of task	(Burrows)
4:30	Closing comments/wrap-up/next meeting plans	(co-chairs)
5:30	Adjourn	

Search for Earth-like Planets Strategic Roadmap Committee
Committee Roster

Ghassem Asrar *co-chair*
Deputy Associate Administrator, Science Mission Directorate, NASA

Adam Burrows, *co-chair*
University of Arizona

David Spergel, *co-chair*
Princeton University

Gerald Chodil
Ball Aerospace (*retired*)

Tom Greene
NASA Ames Research Center

Maureen Heath
Northrop Grumman Space Technology

Geoff Marcy
University of California, Berkeley

Frank Martin
Lockheed Martin (*retired*)

John Mather
NASA Goddard Space Flight Center

Victoria Meadows
Jet Propulsion Laboratory

Neil Tyson
American Museum of Natural History

Alycia Weinberger
Observatories of the Carnegie Institution of Washington

Rich Capps
APIO Coordinator
Jet Propulsion Laboratory

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Search for Earth-like Planets Strategic Roadmap Committee
March 29–30, 2005
Nassau Inn
Princeton, New Jersey

MEETING ATTENDEES

Committee Members:

Burrows, Adam, *co-chair*	University of Arizona
Spergel, David, *co-chair*	Princeton University
Greene, Thomas	NASA Ames Research Center
Heath, Maureen	Northrop Grumman Space Technology
Marcy, Geoff	University of California, Berkeley
Martin, Frank	retired
Mather, John	NASA Goddard Space Flight Center
Meadows, Victoria	NASA/JPL
Smith, Eric, *Designated Federal Official*	NASA Headquarters
Tyson, Neil	American Museum of Natural History
Weinberger, Alycia	Carnegie Institution of Washington

NASA Attendees:

Blackwood, Gary	NASA/JPL
Capps, Rich	NASA/JPL
Devirian, Michael	NASA/JPL
Gallagher, David	NASA/JPL
Heap, Sally	NASA/GSFC
Kinney, Anne	NASA Headquarters
Lapiana, Lia	NASA Headquarters
Lawson, Peter	NASA/JPL
Leisawitz, David	NASA/GSFC
Moore, Michael	NASA Headquarters
Pengra, Patricia	NASA Headquarters
Ridgway, Stephen	NASA Headquarters
Shao, Michael	NASA/JPL

Other Attendees:

Belikov, Ruslan	Princeton University
Bennett, David	University of Notre Dame
Bunner, Alan	Not identified
DeVore, Edna	SETI Institute (*ex officio* committee member)
Fischer, David	Ball Aerospace
Katt, Robert	INFONETIC
Kuchner, Marc	Princeton University
Moto-Martin, Amaya	Princeton University
Sumi, Taka	Princeton University

Search for Earth-like Planets Strategic Roadmap Committee
March 29–30, 2005
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Princeton, New Jersey

LIST OF PRESENTATION MATERIAL[1]

1. Anne Kinney, Director, Universe Division, NASA Science Mission Directorate. *Terrestrial Planet Finder Status.* March 30, 2005.
2. "Terms of Reference: NRC Assessment of Strategic Roadmaps"
3. David Spergel. *Search for Earth-Like Planets. Strategic Roadmap #4. Interim Report. April 15, 2005.* (Working draft and outline, including guidance on interim report format and content.)
4. David Gallagher. *SIM PlanetQuest Redesign*. March 30, 2005.
5. Michael Shao. *SIM PlanetQuest Redesign. Science Impact and How SIM Helps TPF-C Characterize More Terrestrial Planets*. March 30, 2005.
6. David Bennett, University of Notre Dame. *Terrestrial Planets and Dark Energy with a Wide FOV Space Telescope. The science of the Microlensing Planet Finder (MPF) and JDEM with a single mission.*
7. Dave Leisawitz, Observational Cosmology Lab, NASA Goddard Space Flight Center. *High Angular Resolution in the Far-IR: An Essential Measurement Capability*.
8. Lee Feinberg et al., Advanced Telescopes and Observatories CRM Team. *Advanced Telescopes and Observatories Capability Roadmap*. Presentation to the National Research Council.
9. Paul Hertz, Assistant Associate Administrator for Science, Science Mission Directorate. *Science Integration*. Presentation for the joint meeting of the SScAC and ESSAAC, March 30, 2005.

[1] Presentation and other materials distributed at the meeting are on file at NASA Headquarters, Science Mission Directorate, Washington, DC 20546. For access, contact Dr. Eric Smith, the Designated Federal Official.